EGU General Assembly 2019:

Opposing influences of Arctic sea-ice loss on Californian and Mediterranean rainfall

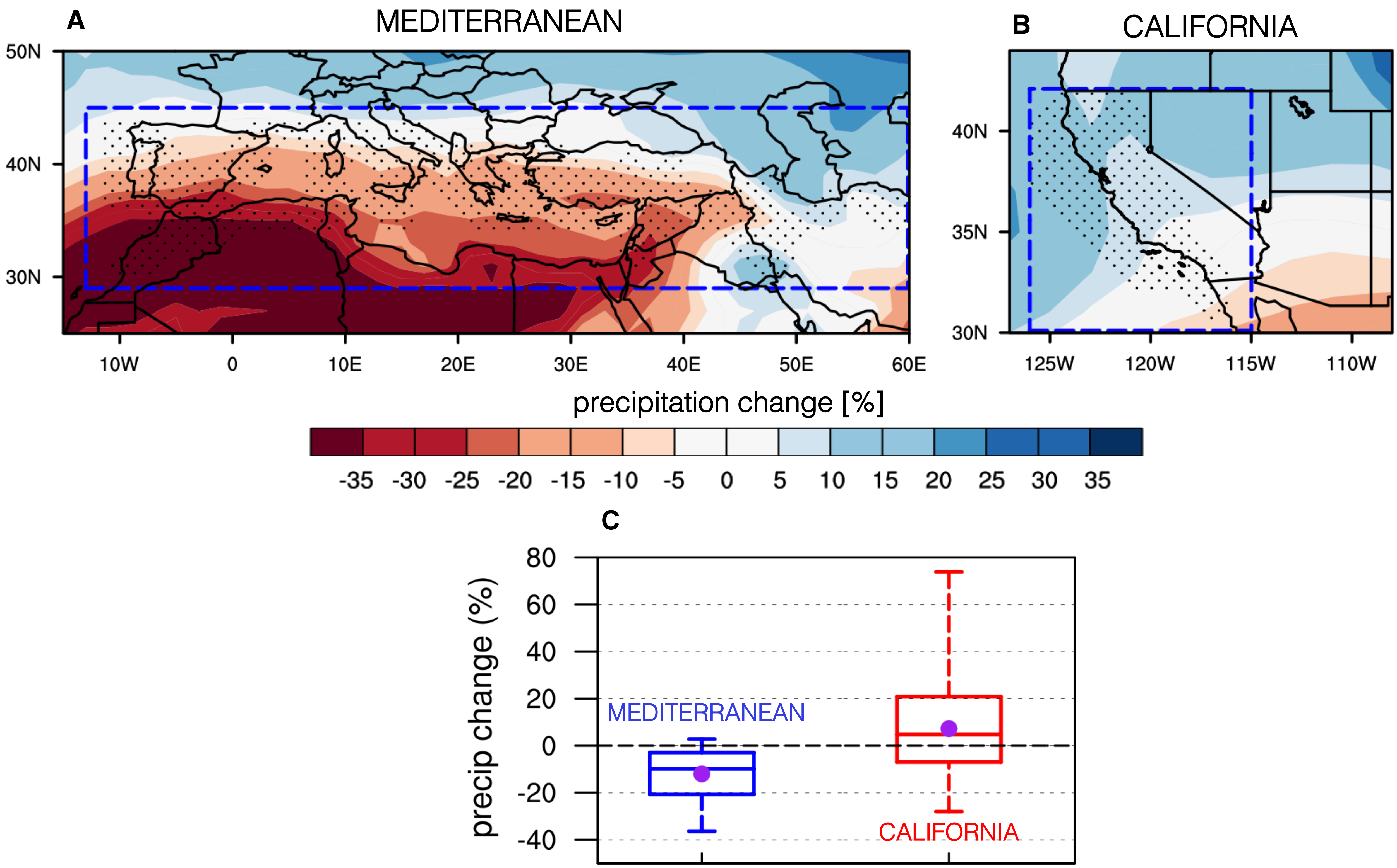
Ivana Cvijanovic[1], Benjamin Santer[2], Donald Lucas[2], Celine Bonfils[2], John Chiang[3], Rachel White[1], Xavier Levine[1] and Pablo Ortega[1]

(1) Barcelona Supercomputing Center, Barcelona, Spain,
(2) Lawrence Livermore National Laboratory, Livermore, California, USA
(3) University of California Berkeley, Berkeley, California, USA

April 10, 2019

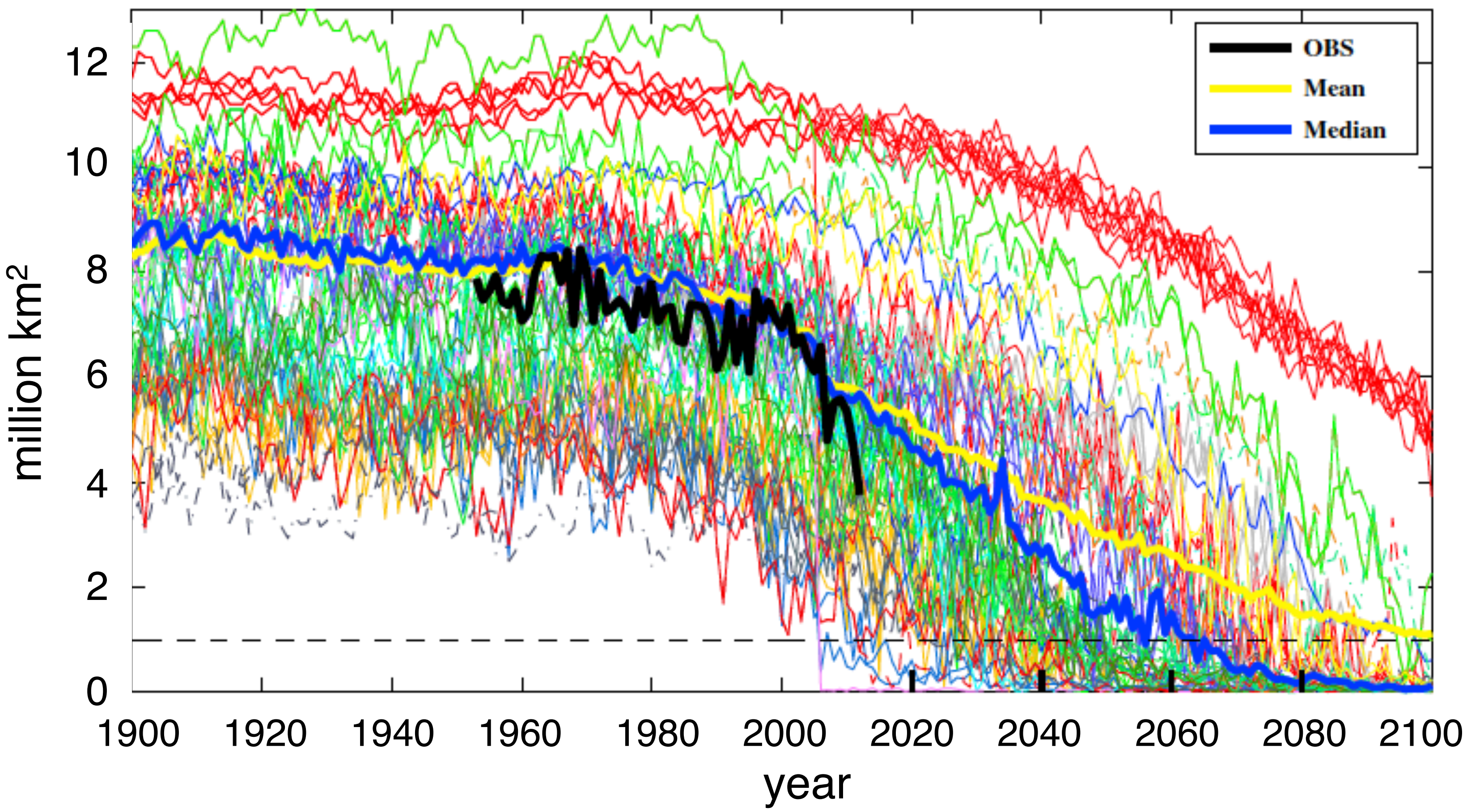
Polade et al. (2017): California and Mediterranean Basin are regions with some of the highest uncertainties in projections of future precipitation changes

36-model mean (CMIP5), 2060-2089 – 1960-1989:

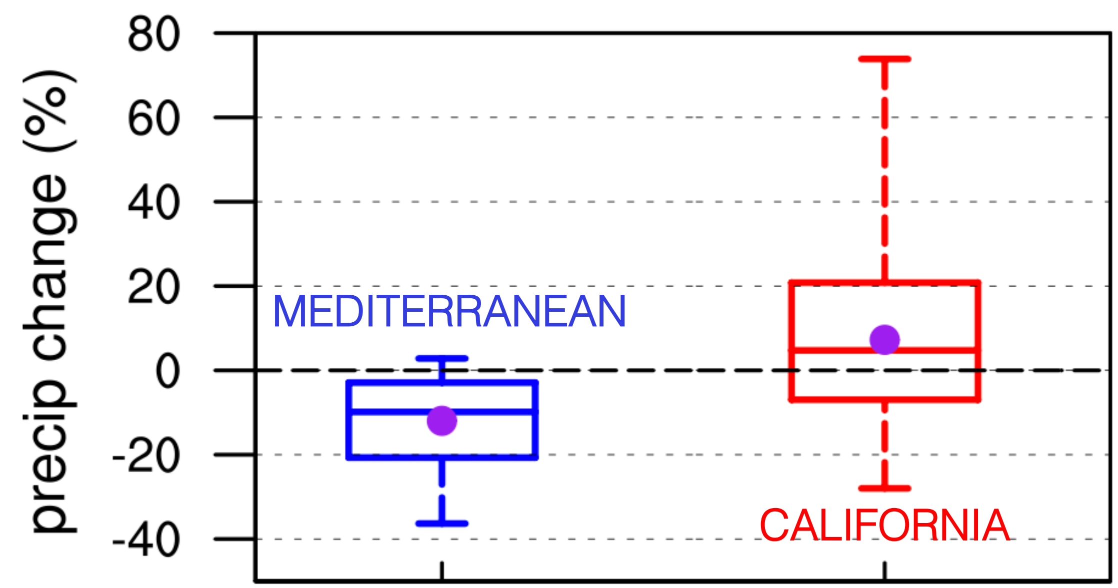


Multimodel spread in CMIP5 projections of historical and future Arctic sea-ice loss cover has not been small either

September Sea Ice Extent, Overland and Wang (2013):



Are the uncertainties linked ???

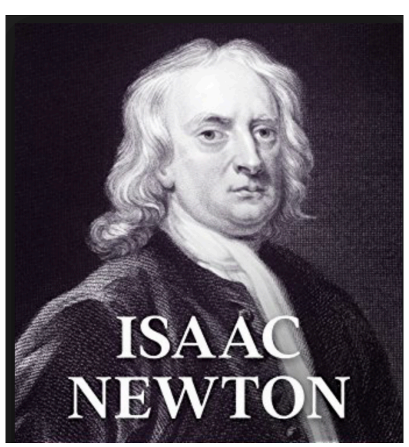


Methodological objective

Improve the existing methods for isolating the impacts of sea ice changes on climate:

1. Allow for full propagation of atmospheric teleconnections (do not expect teleportation)

2. Do not “paint the sea-ice black”



3. Do not ignore fundamental physical laws

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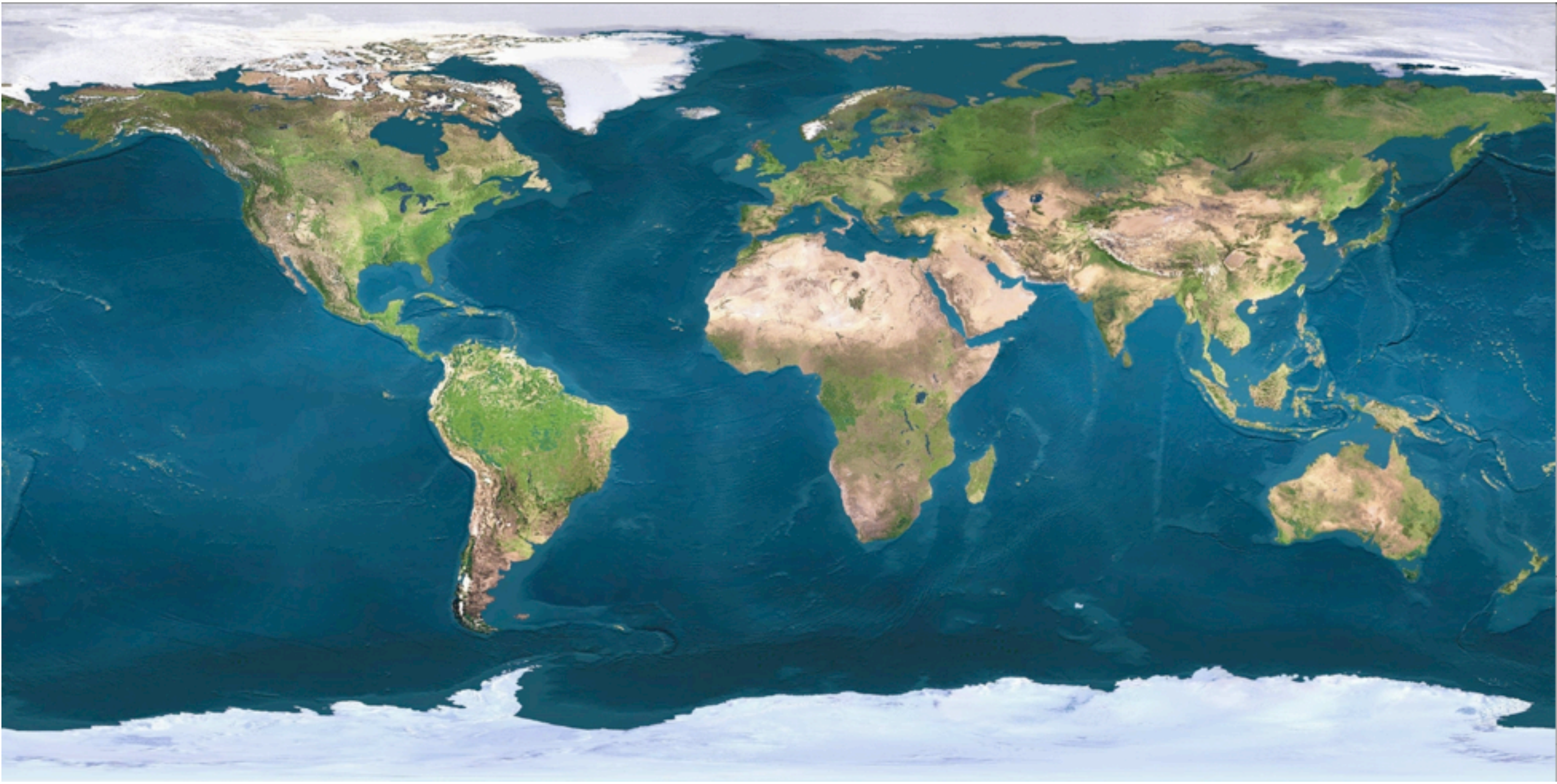

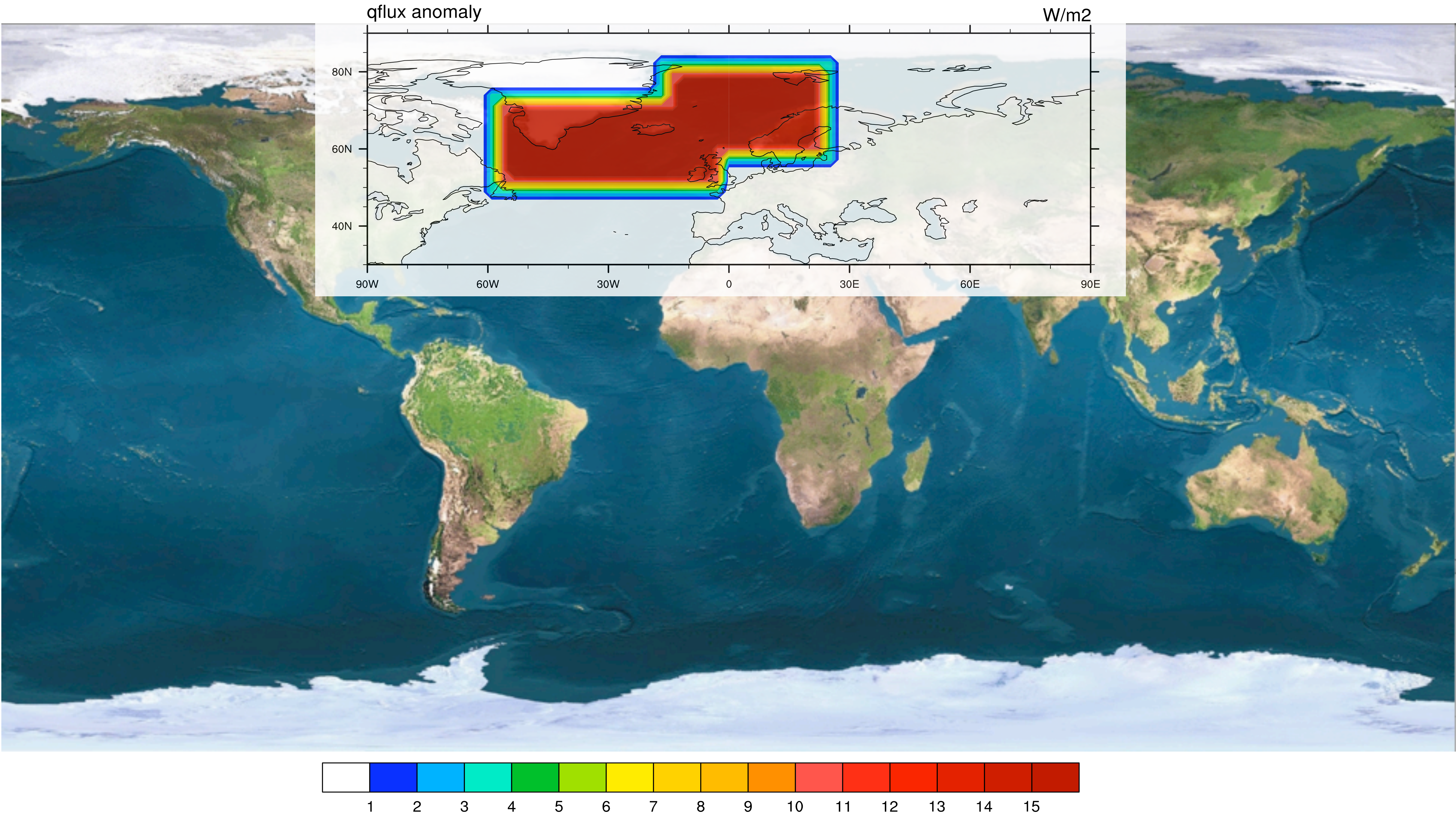
qflux anomaly
W/m2
80N
60N
40N
90W
60W
30W
0
30E
60E
90E
1
2
3
4
5
6
7
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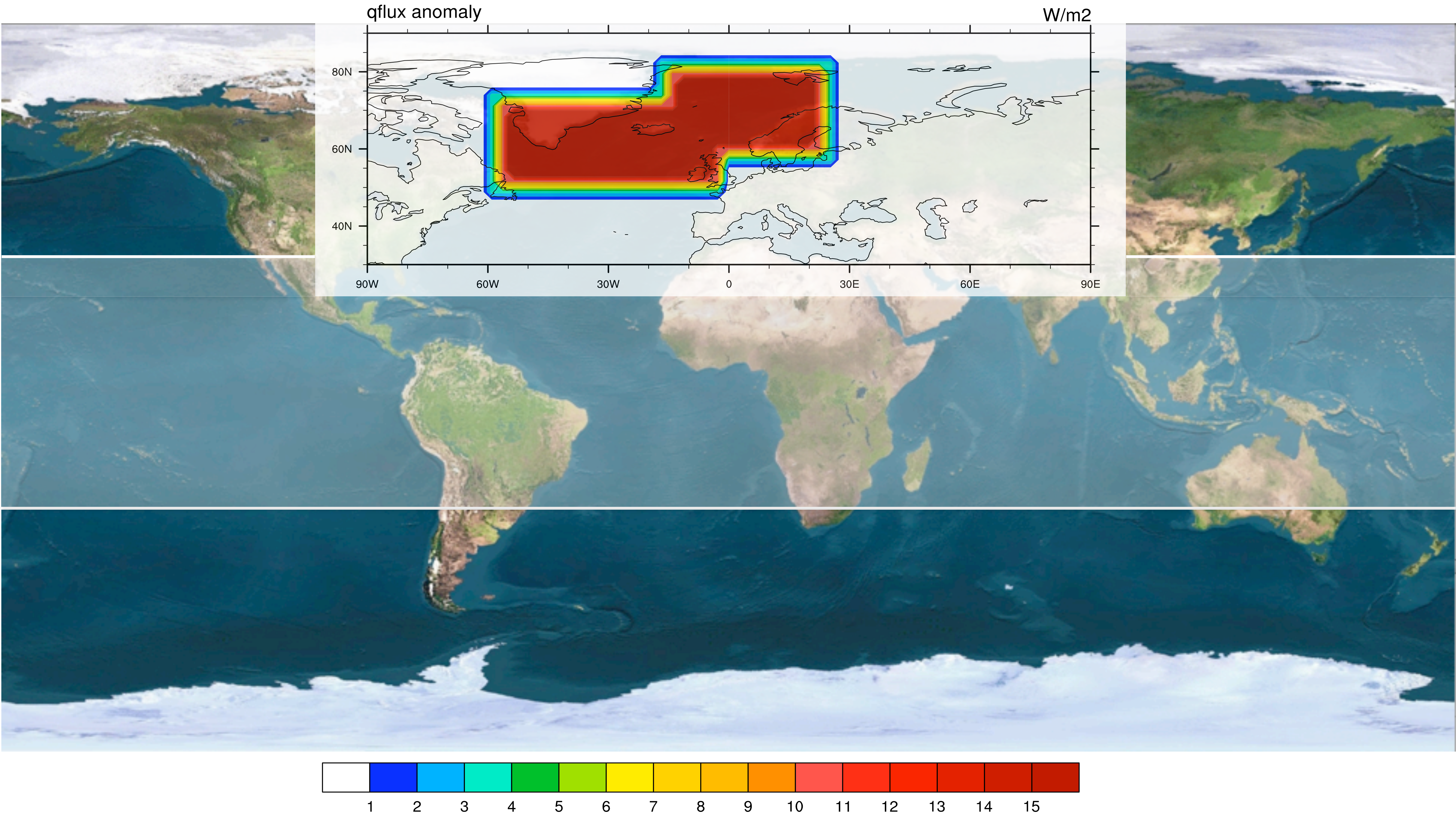
11
12
13
14
15



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W/m2
80N
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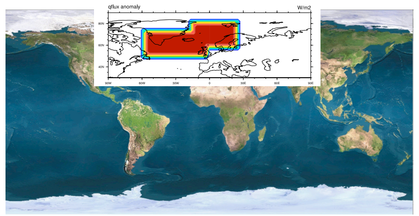
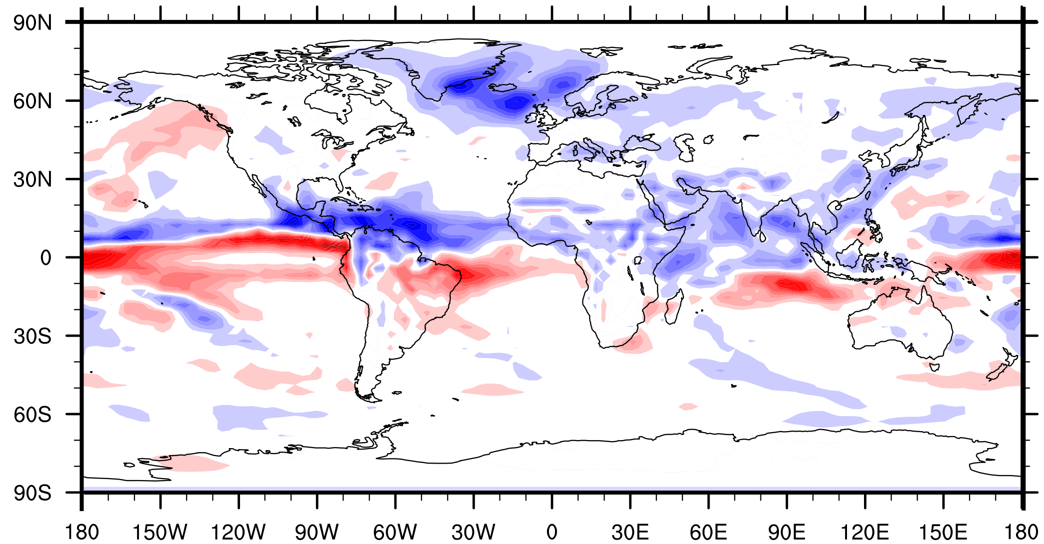
Tropical precipitation response to high latitude cooling: interactive vs. prescribed SSTs
(Cvijanovic and Chiang 2013, Climate Dynamics)

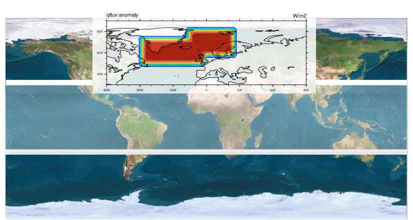
1.



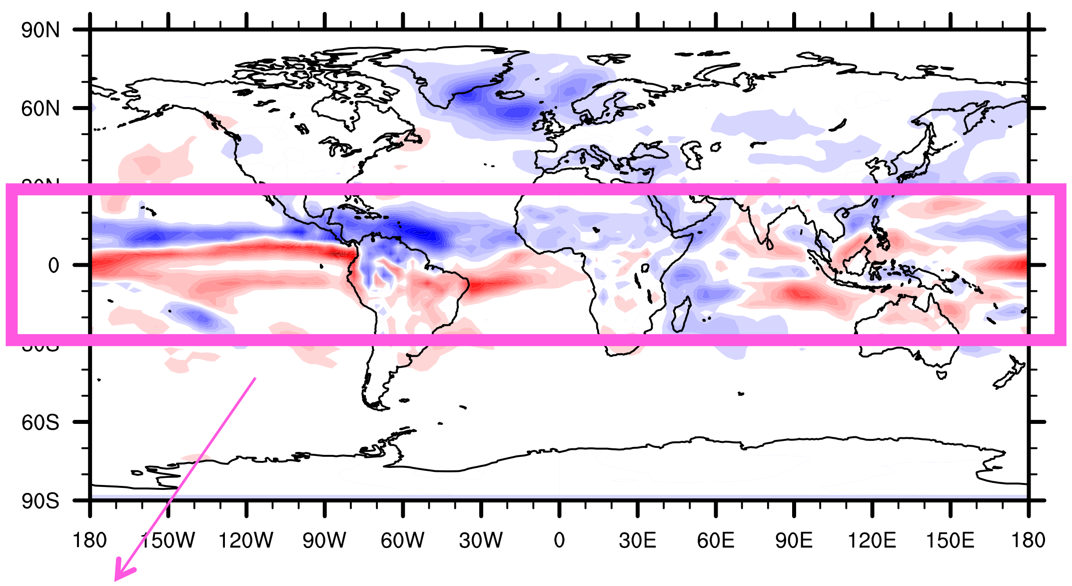
slab ocean (interactive SSTs)



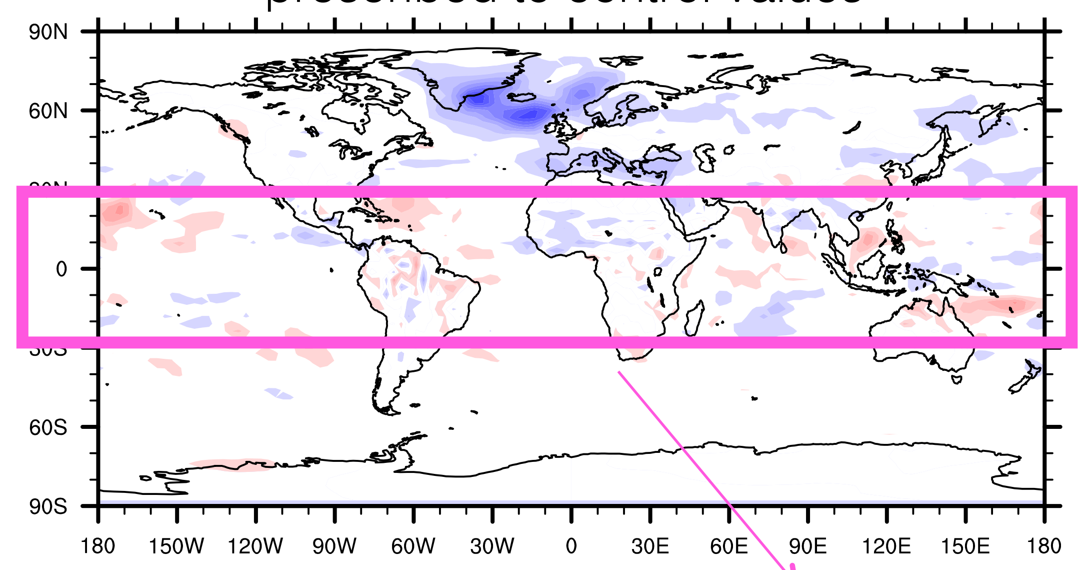
2.



slab ocean with tropical SSTs
prescribed to perturbed values



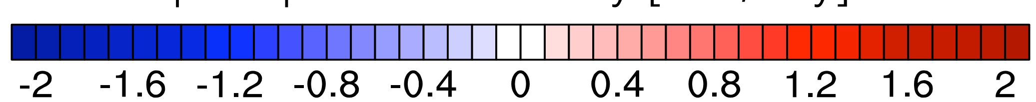
slab ocean with tropical SSTs
prescribed to control values



precipitation shift!

no precipitation shift!

precipitation anomaly [mm/day]



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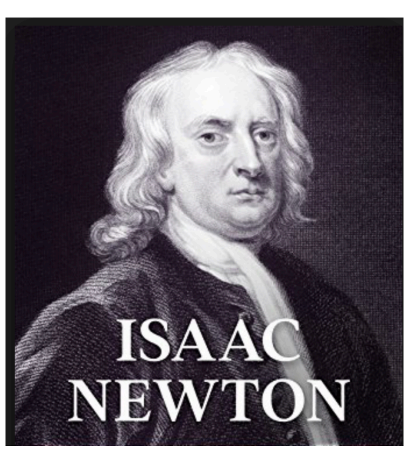

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Perturbed sea-ice physics parameter simulations (PSIPPS)

Apply small perturbations to the sea ice physics parameters that have largest impact on the resulting sea-ice cover (after Lucas et al. 2013)

parameter	default value	expert defined range
snow grain radius tuning parameter	1.5	-1.9 - 1.9
snow melt maximum radius	1500	500 - 2000
thermal conductivity of snow	0.3	0.1 - 0.35

low Arctic ice "formula"

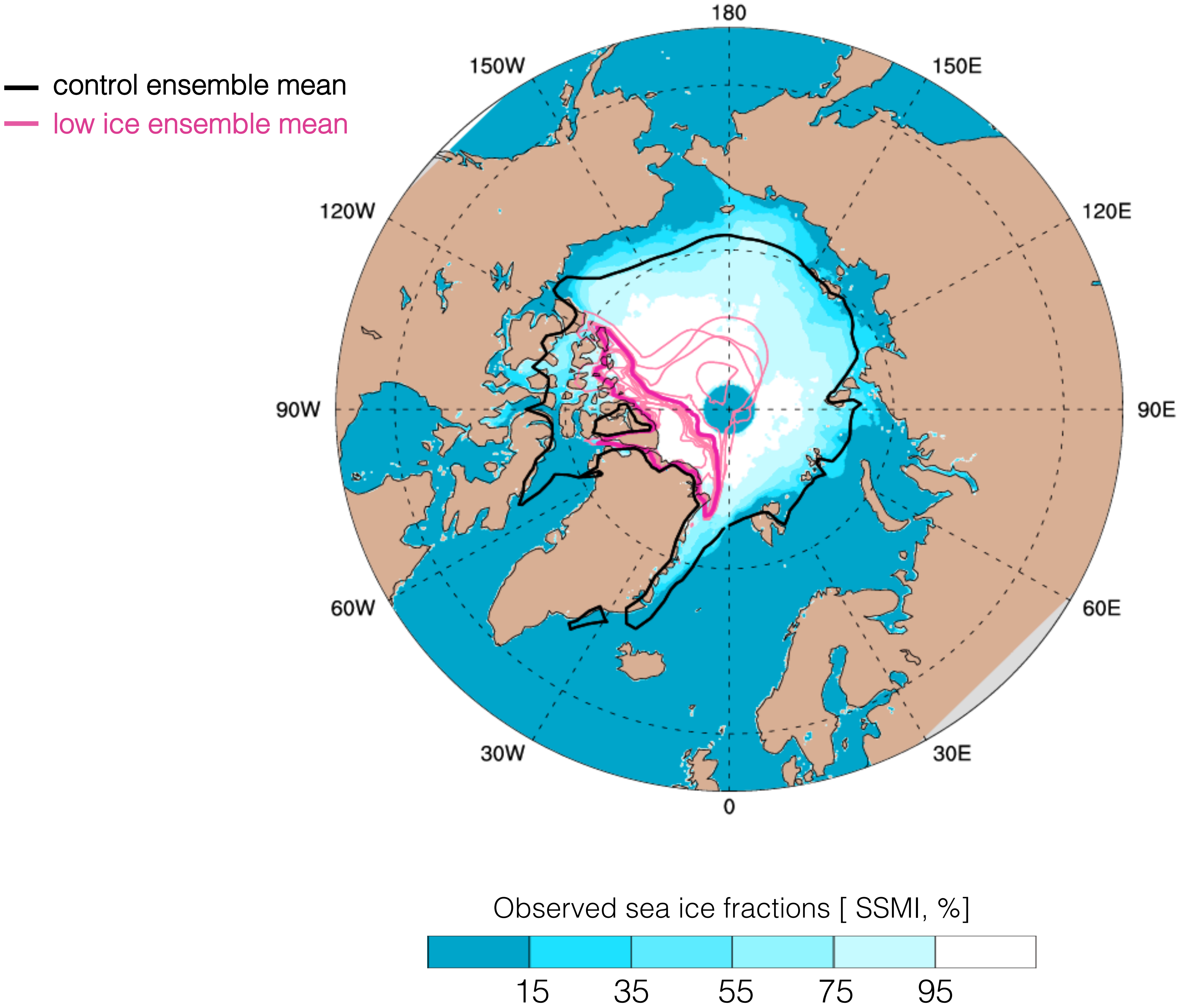
Model: Community Atmosphere Model version 4 (CAM4) + Community Land Model version 4 (CLM4) + Community Ice CodeE 4 (CICE4) coupled to a slab ocean

run type: year 2000 repeat

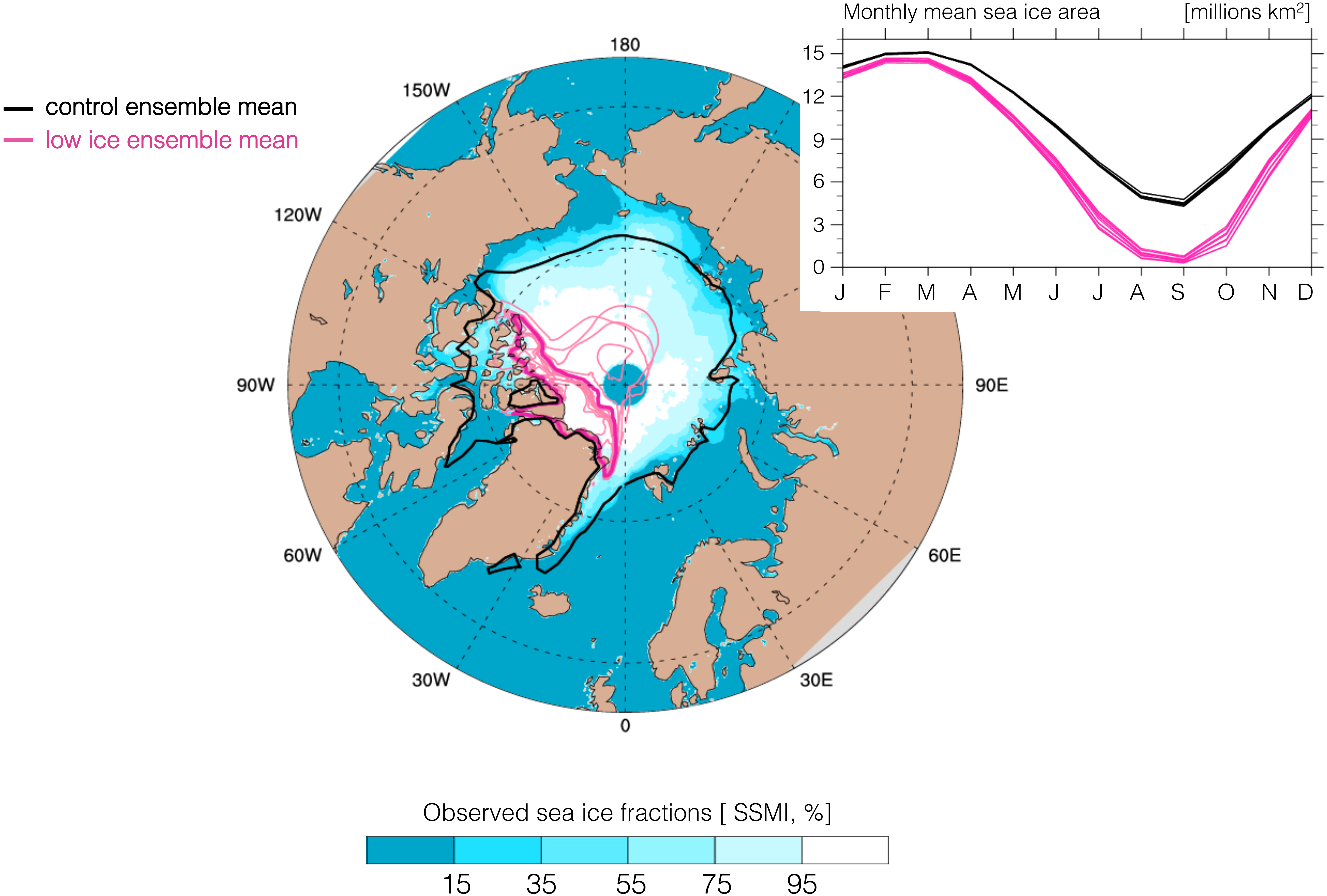
Control simulation: default sea ice parameter values applied in both hemispheres

'low ice' simulations: perturbations applied in one hemisphere at the time

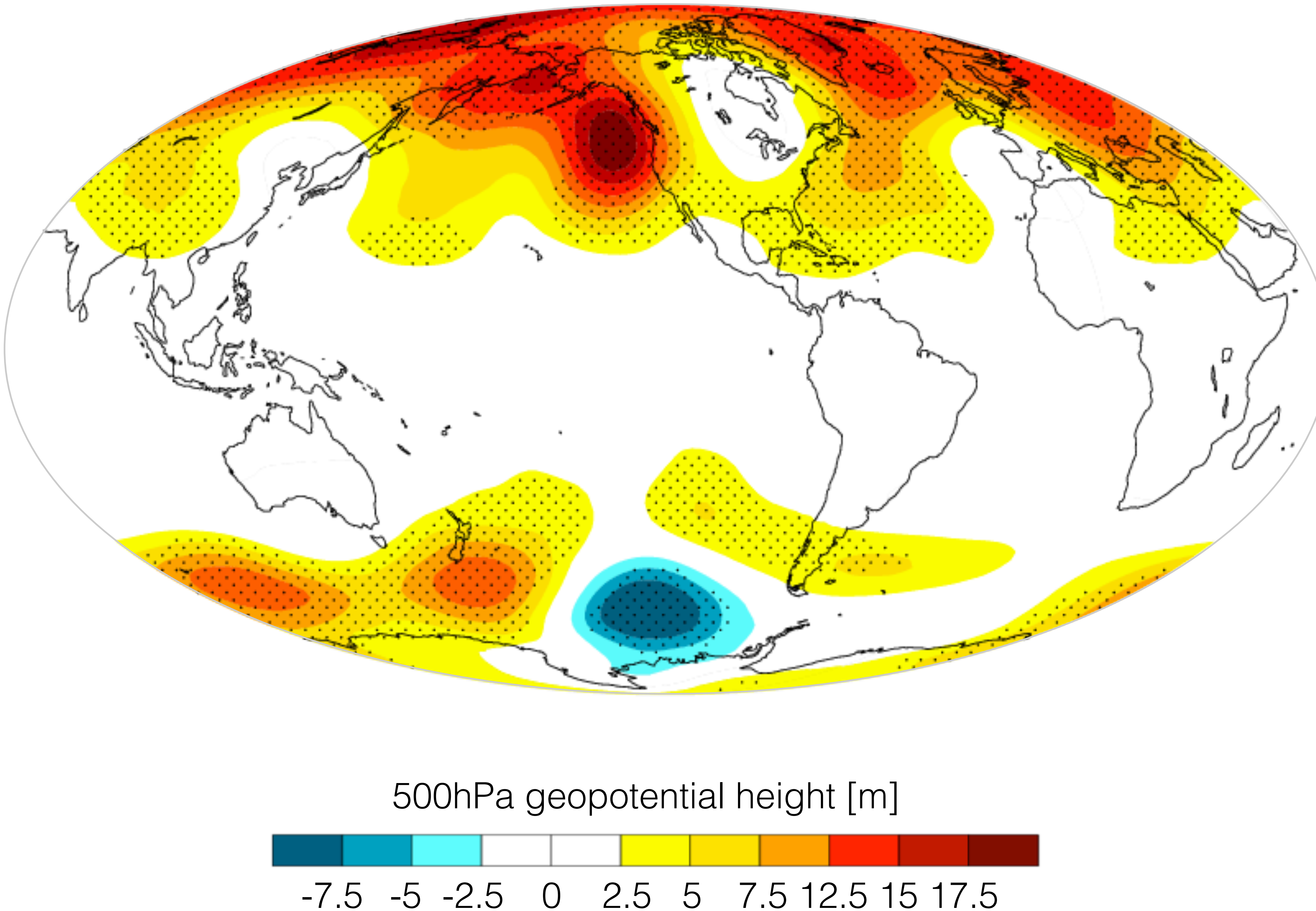
Monthly mean sea ice fractions for September



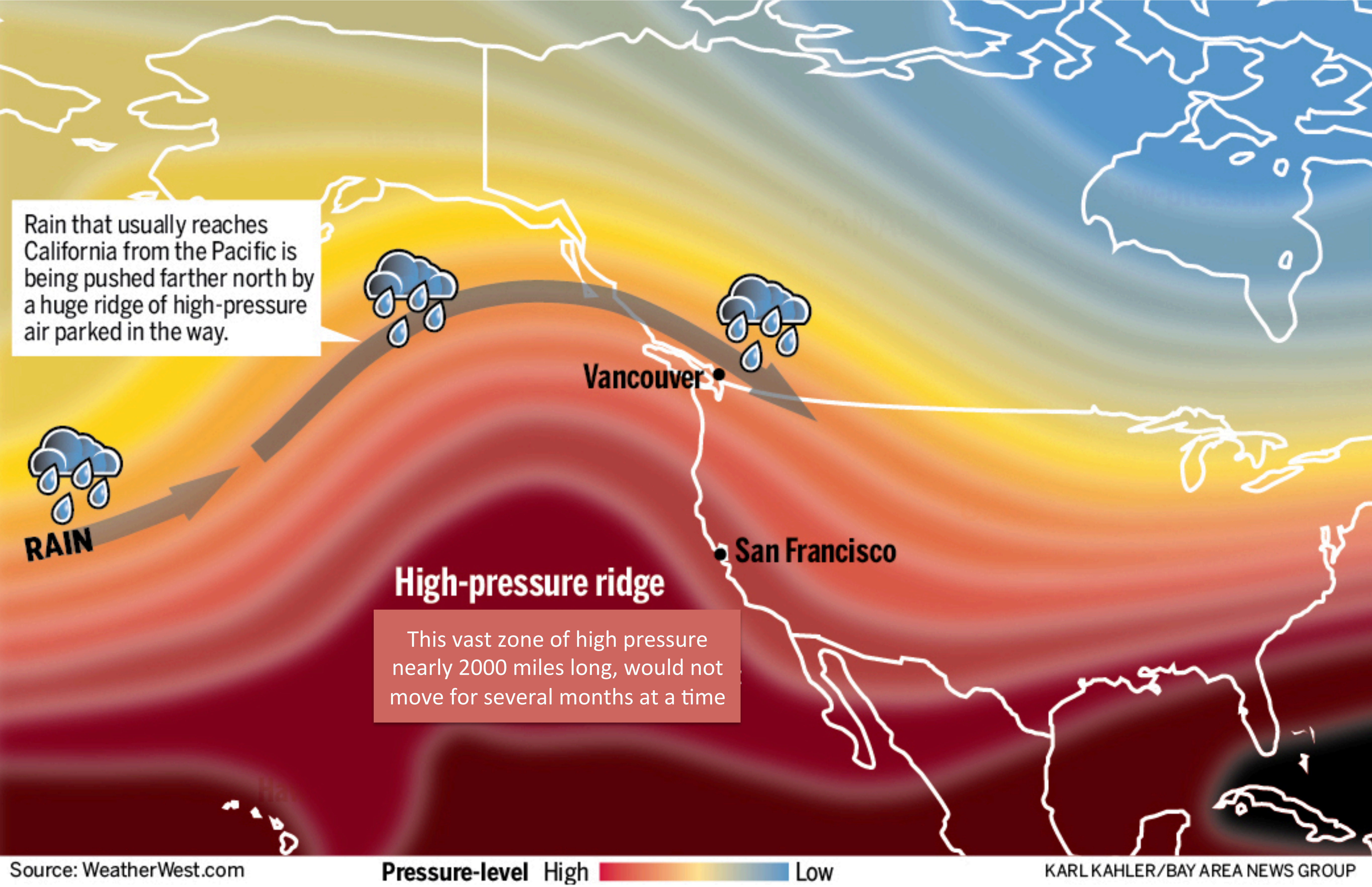
Monthly mean sea ice fractions for September



Dec-Feb 500 hPa geopotential anomalies

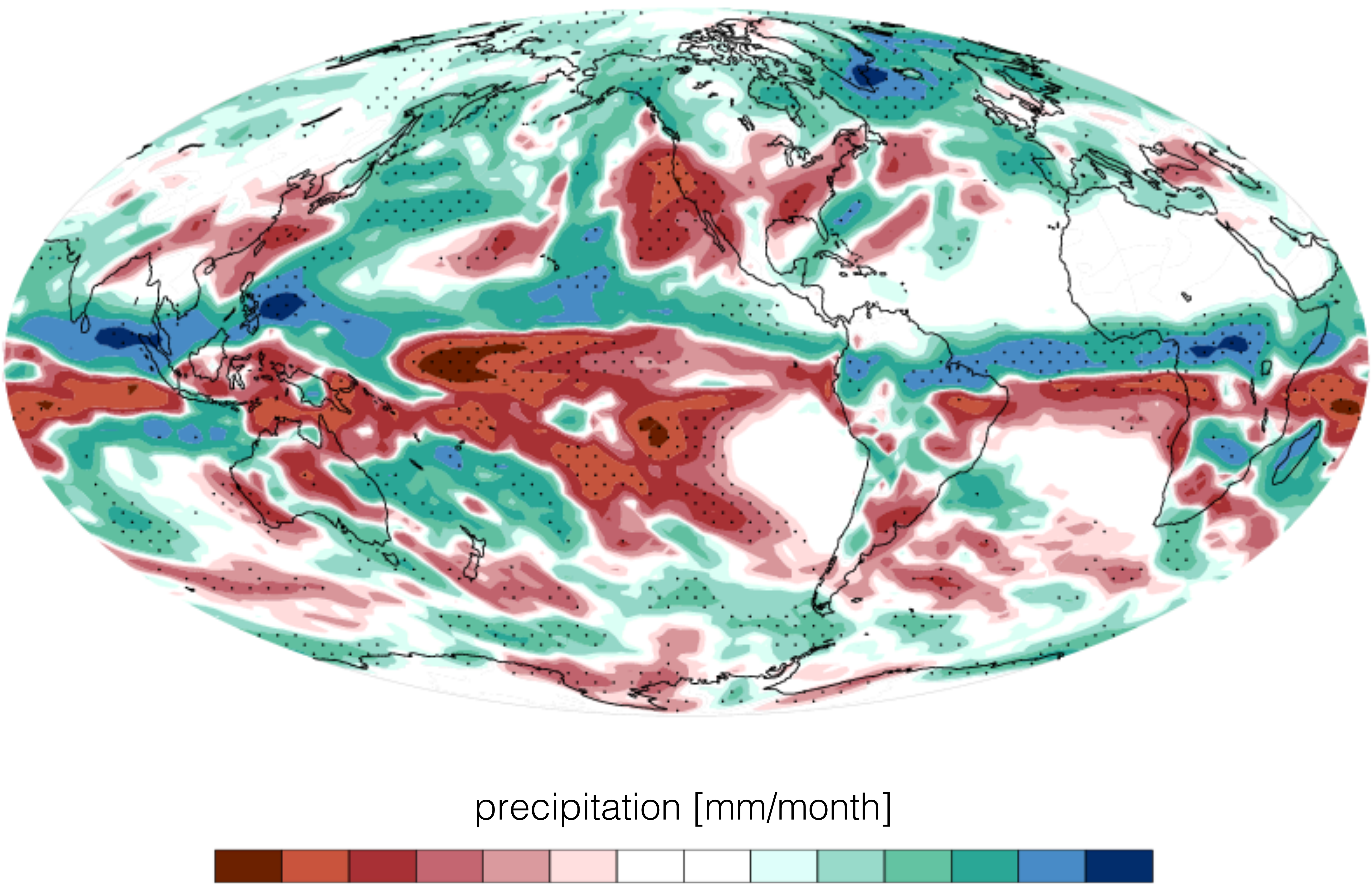


Stippling indicates the anomalies that are statistically significant at the 95% confidence level



Rain that usually reaches California from the Pacific is being pushed farther north by a huge ridge of high-pressure air parked in the way.
RAIN
Vancouver
San Francisco
High-pressure ridge
This vast zone of high pressure nearly 2000 miles long, would not move for several months at a time
Source: WeatherWest.com
Pressure-level High
Low
KARL KAHLER/BAY AREA NEWS GROUP

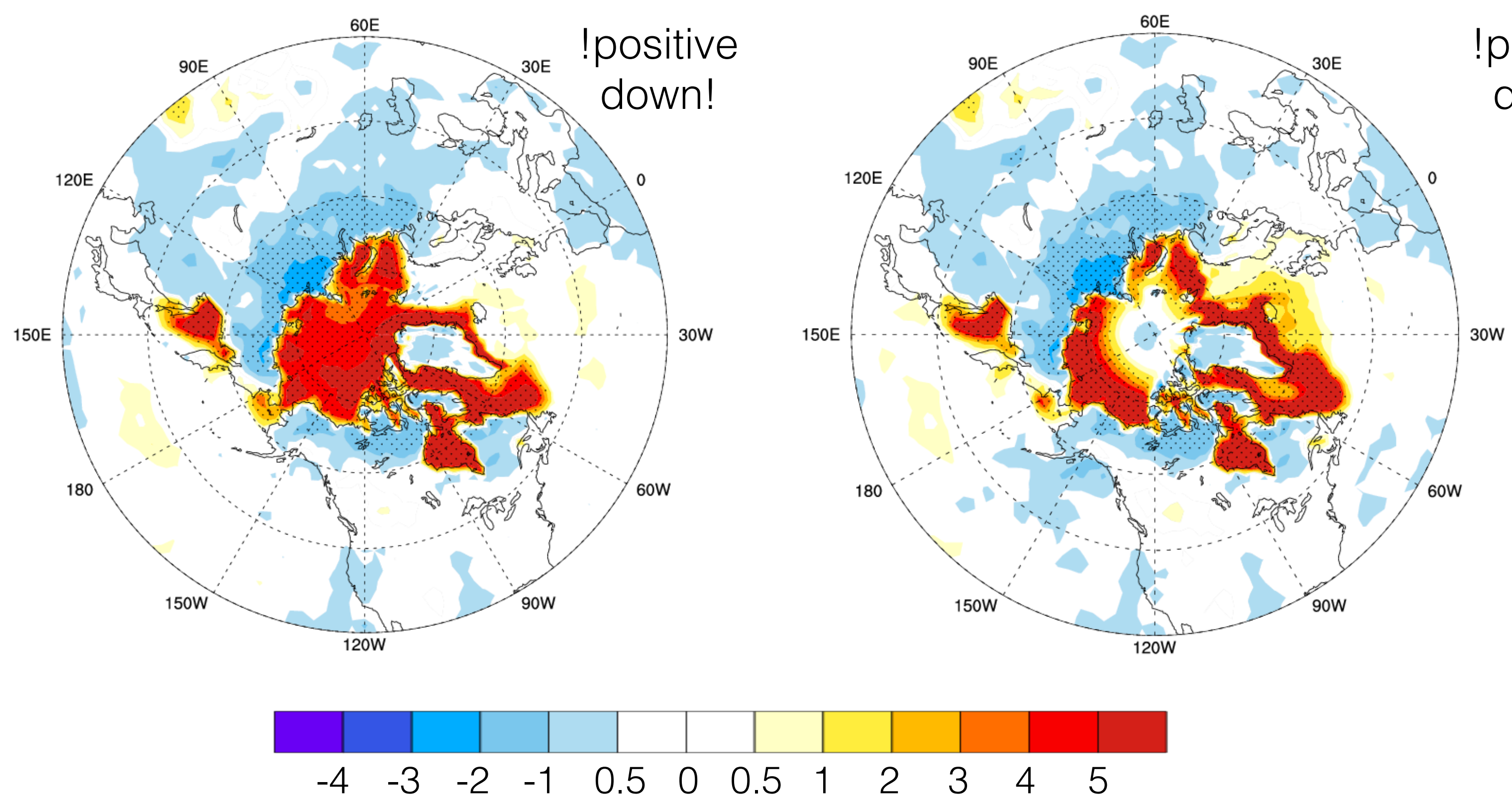
Dec-Feb precipitation anomalies

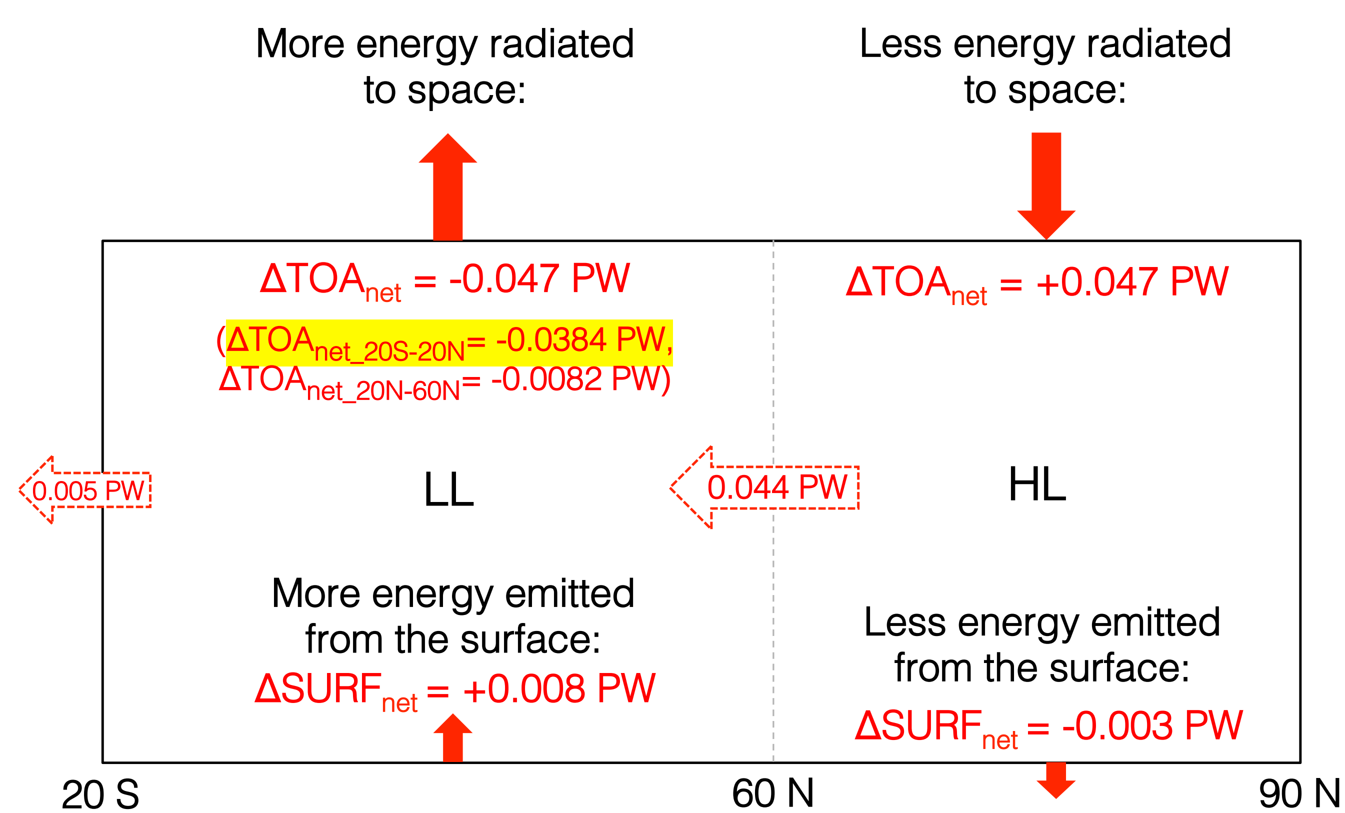


Stippling indicates the anomalies that are statistically significant at the 90% confidence level

Step 1: sea ice decline induced energy imbalance can not be compensated locally, but results in tropical OLR changes

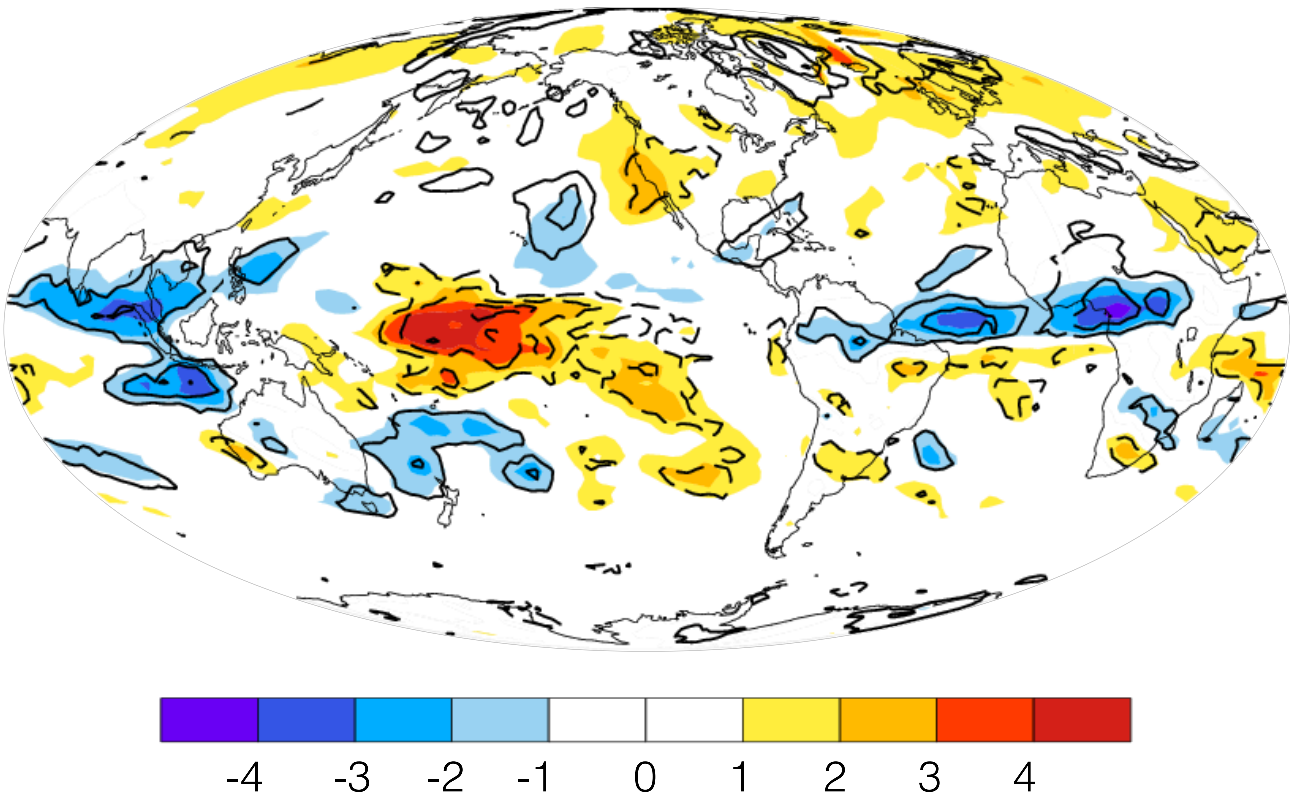
TOA NET energy flux ANN [W/m²]   Column NET energy flux ANN [W/m²]





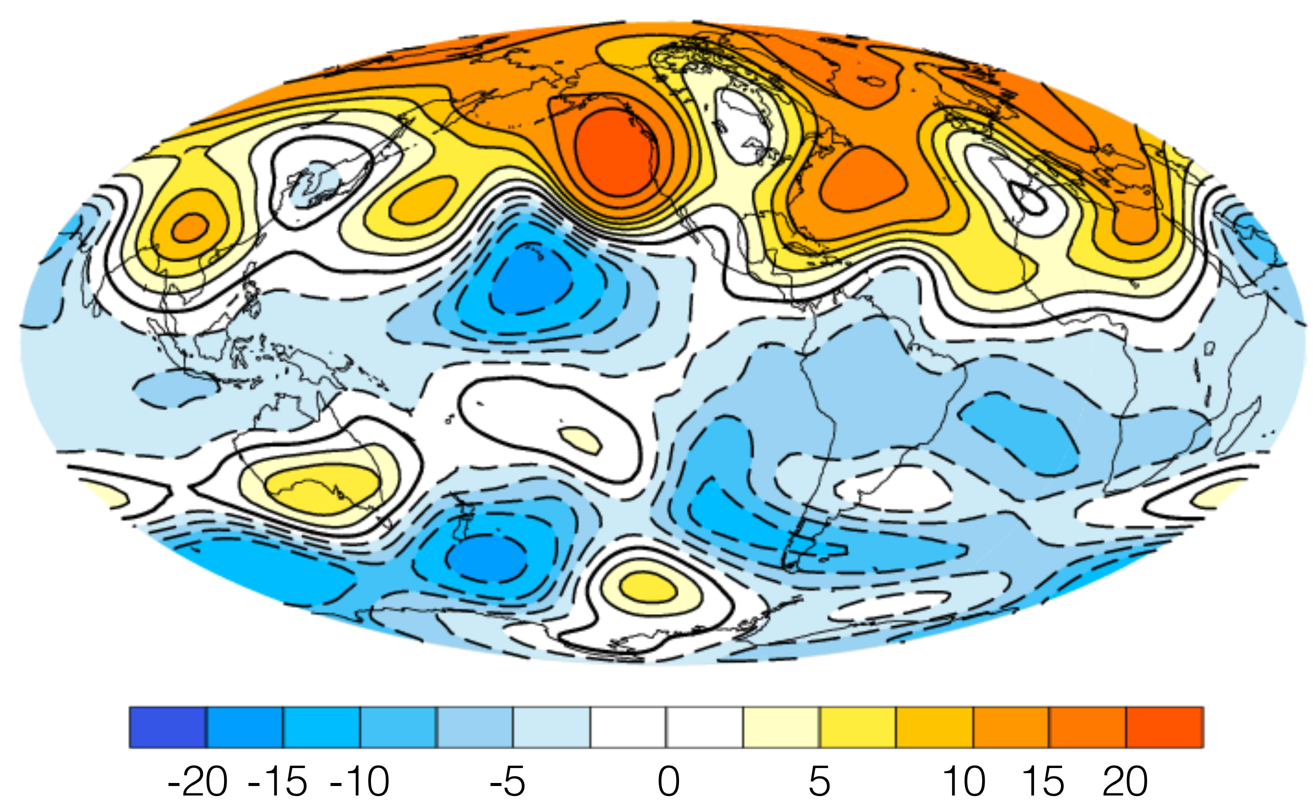
Step 2: tropical convection reorganization forces a Rossby wavetrain

DJF OLR anomalies [W/m^2]

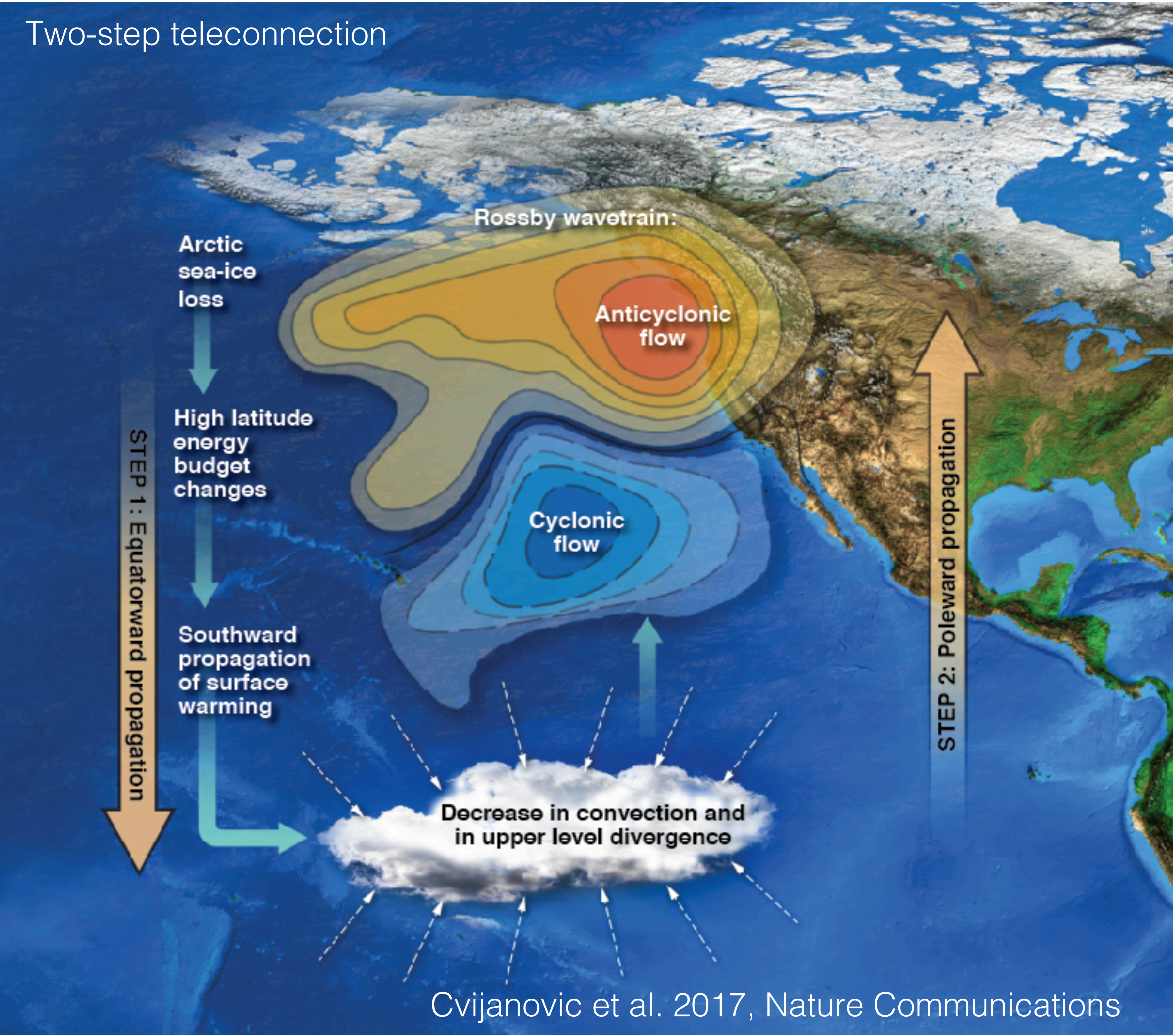


Rossby wavetrain

DJF 250hPa streamfunction changes [x10^5 m^2/s]

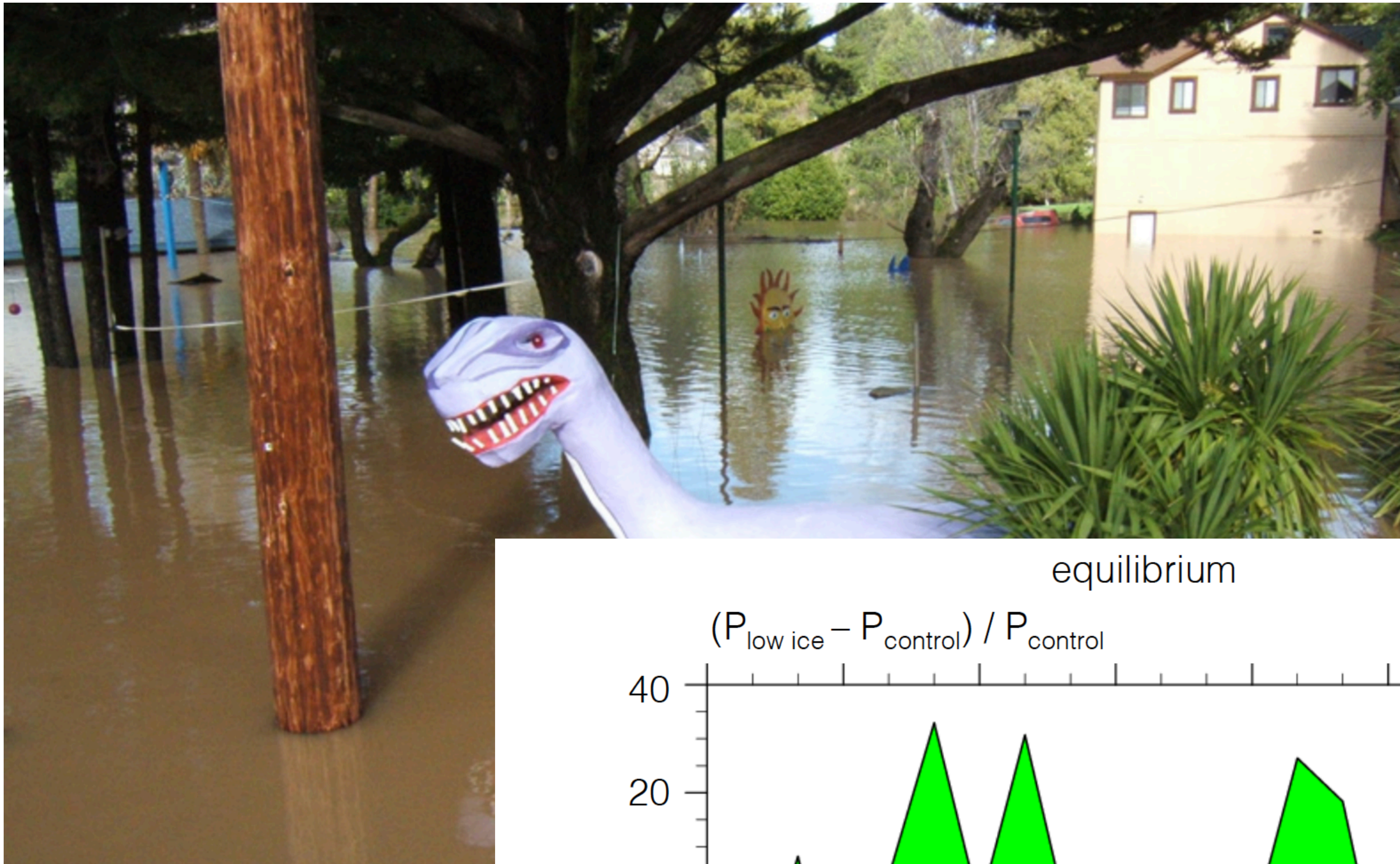


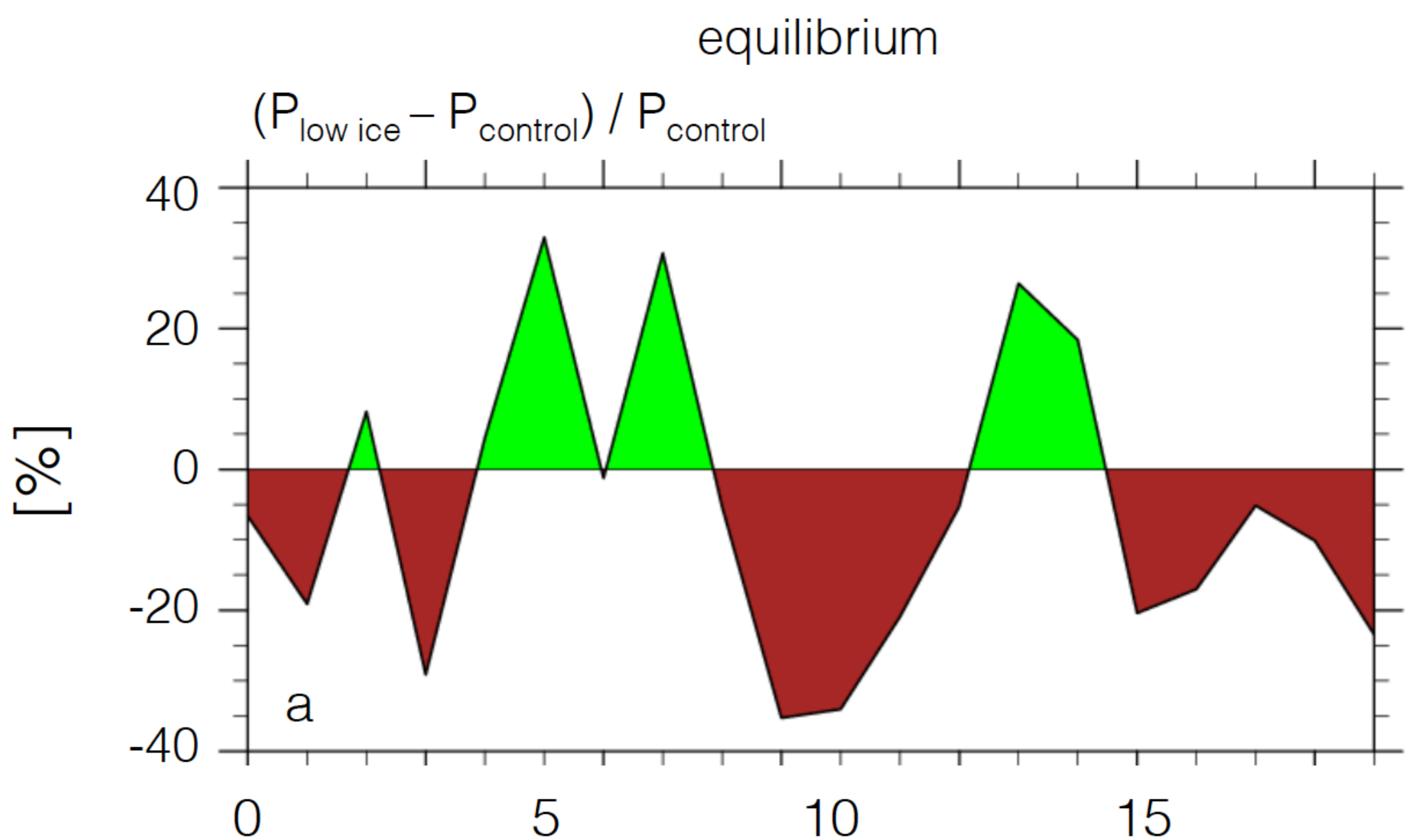
Arctic sea-ice loss induced tropical Pacific convection reorganization drives the Rossby wavetrain resulting in anticyclonic response in the North Pacific:



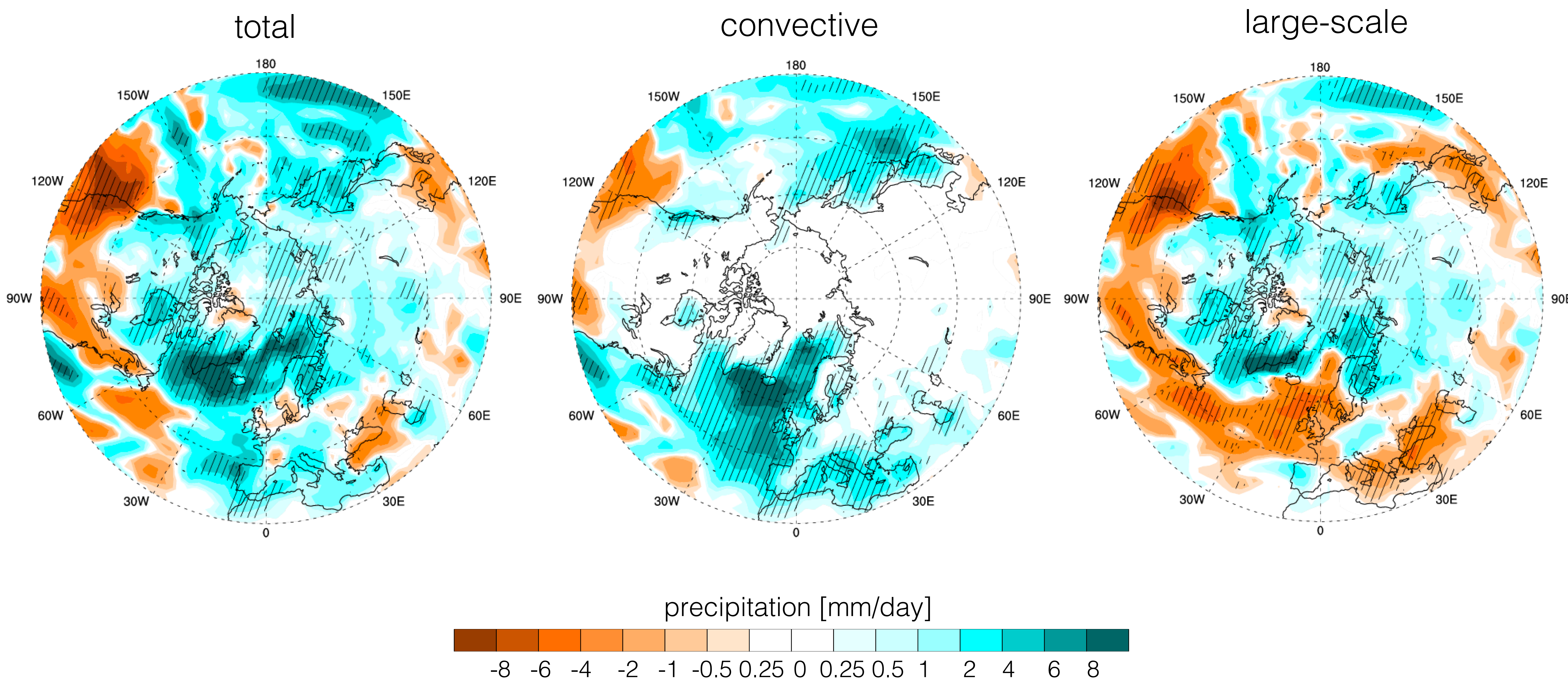
Cvijanovic et al. 2017, Nature Communications

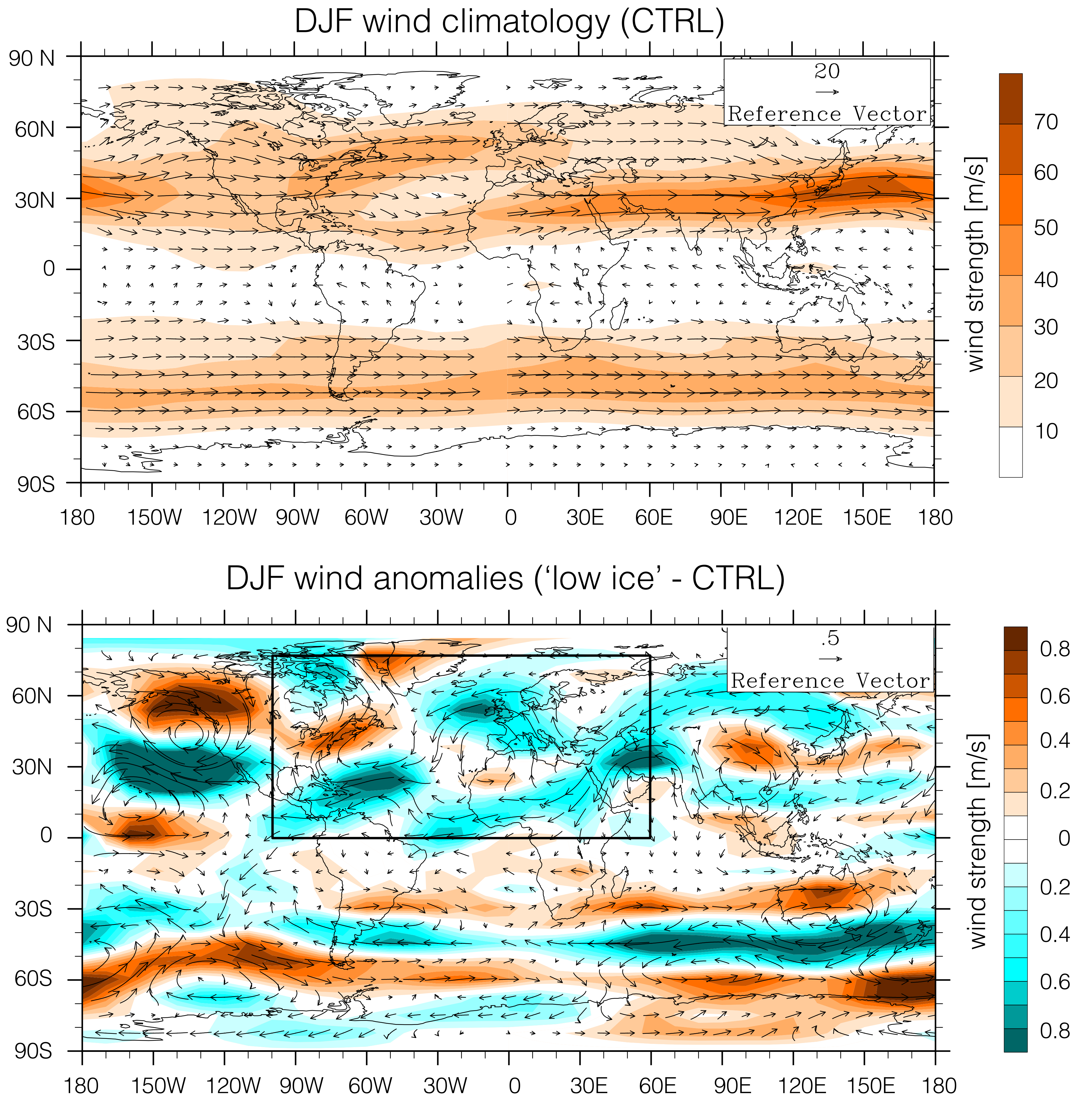
But this winter was quite wet in northern Cal...

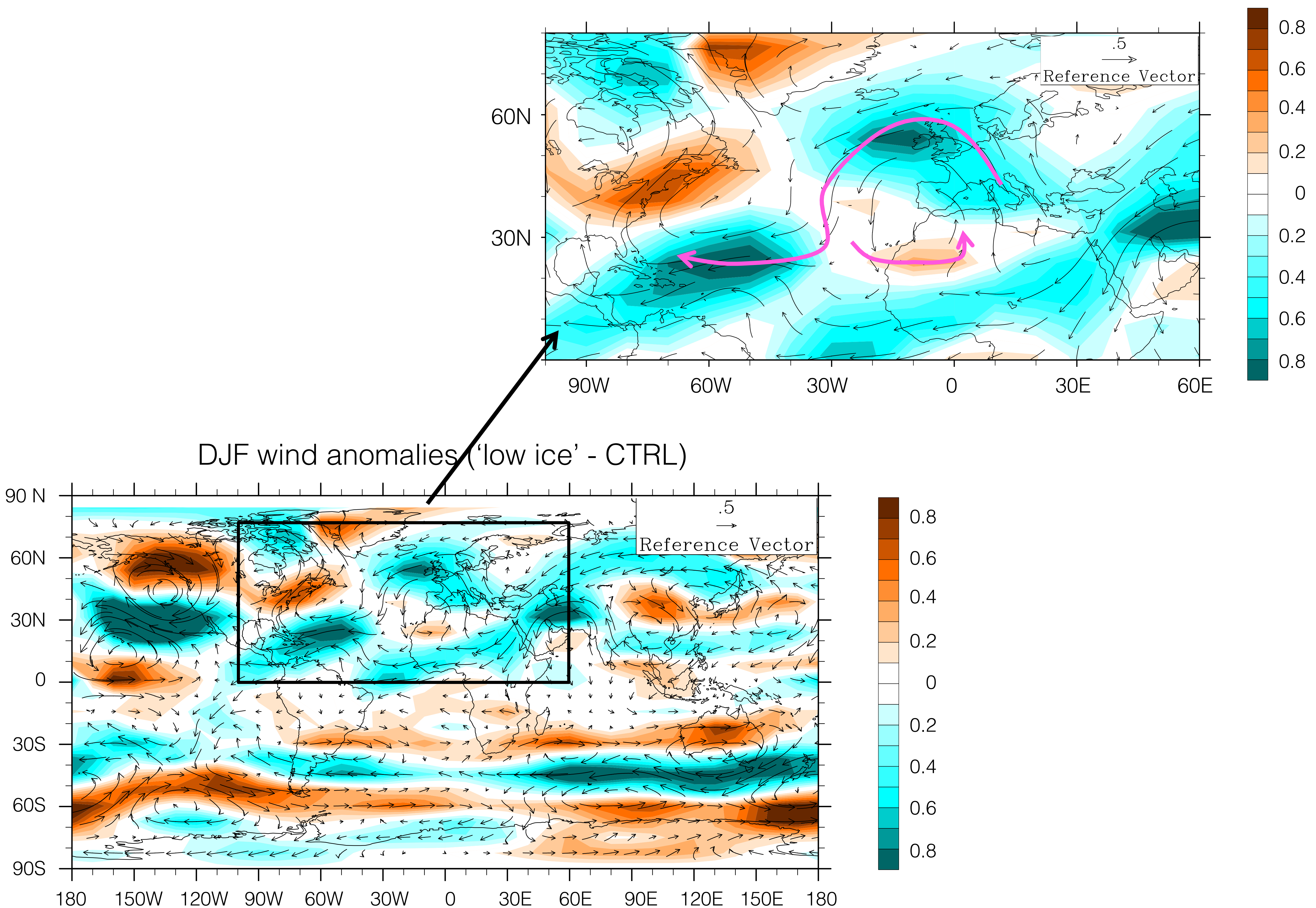




Dec-Feb precipitation anomalies (‘low ice’ – control)




DJF wind climatology (CTRL)
20
Reference Vector
90 N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
wind strength [m/s]
70
60
50
40
30
20
10
DJF wind anomalies ('low ice' - CTRL)
.5
Reference Vector
90 N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
120E
150E
180
wind strength [m/s]
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8



DJF wind anomalies ('low ice' - CTRL)
.5
Reference Vector
60N
30N
90W
60W
30W
0
30E
60E
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
90 N
60N
30N
0
30S
60S
90S
180
150W
120W
90W
60W
30W
0
30E
60E
90E
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150E
180
.5
Reference Vector

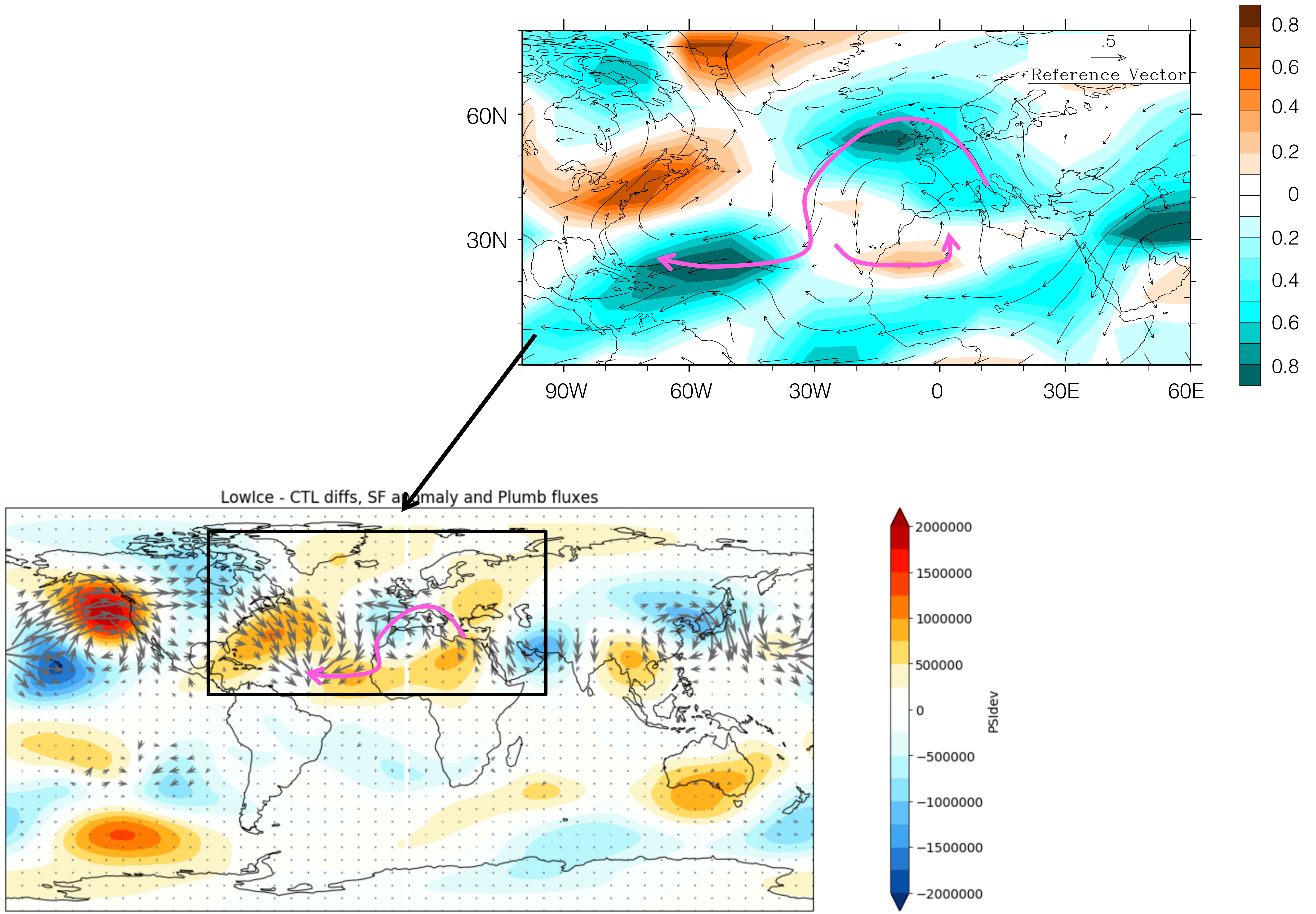
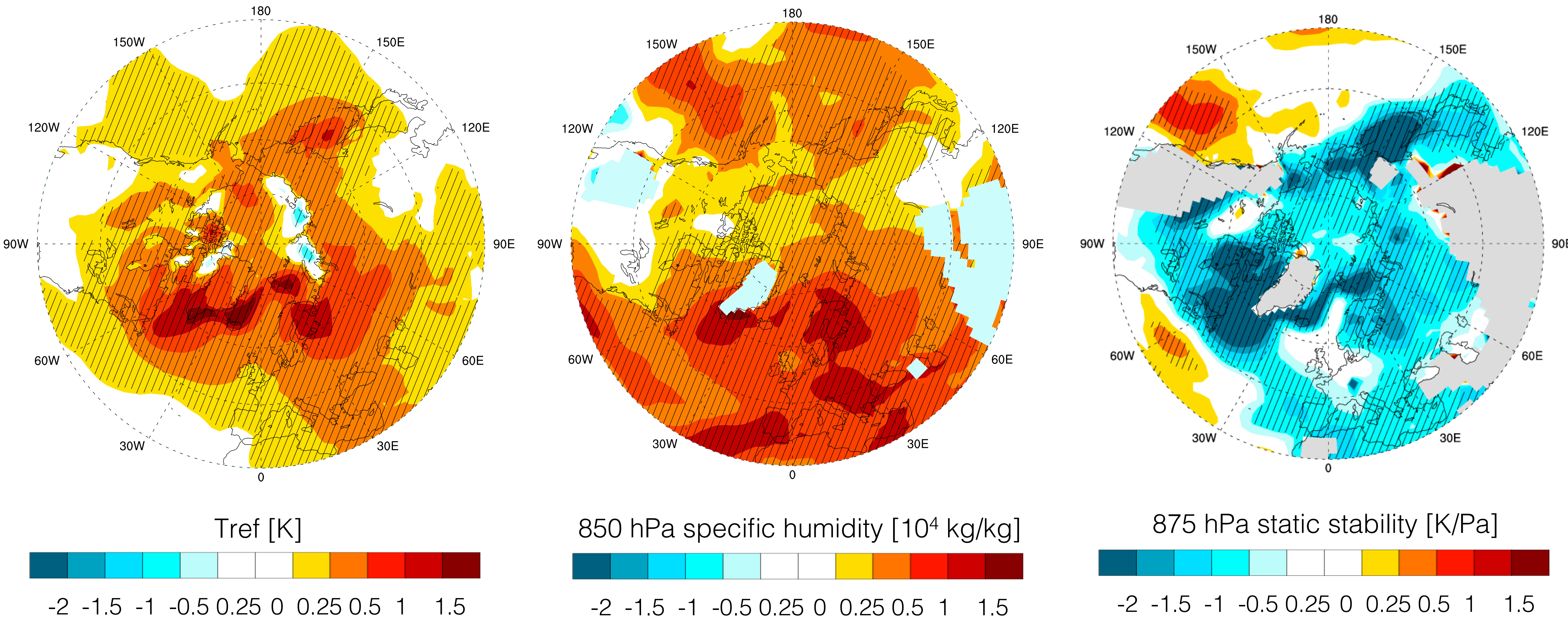


Figure courtesy of Rachel White

Causes of convective precipitation response? ('low ice' – control)



Conclusions and Implications 1

Arctic sea ice loss induces a dynamical forcing that favors drier winter conditions over California and wetter over the Mediterranean

The ability to accurately estimate future precipitation changes over California and Mediterranean could be dependent on the fidelity with which future sea ice changes are simulated

!!! Studies that attempt to infer the influence of sea ice loss with a prescribed SST framework may not capture the described two–step teleconnection; imposing high latitude energy budget perturbations will have an impact on tropical teleconnections

Conclusions and Implications 2

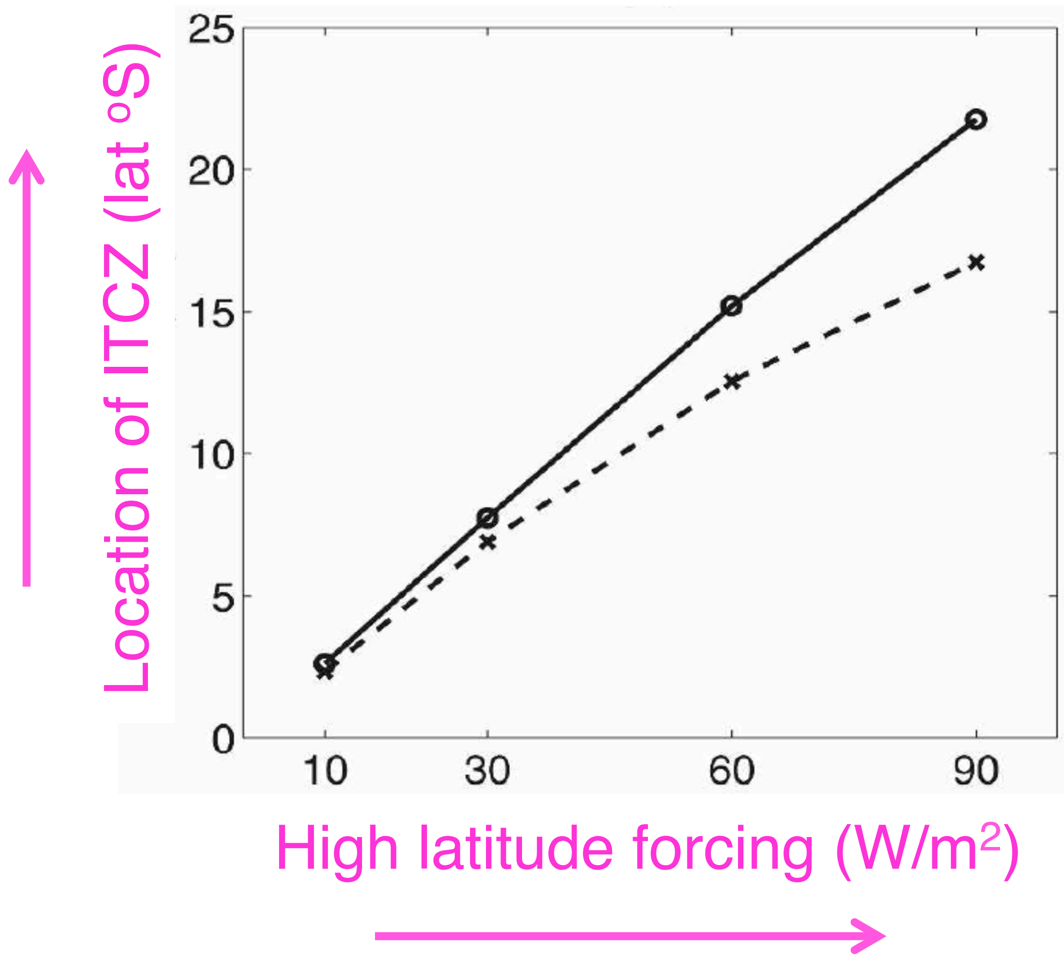
Thanks to:

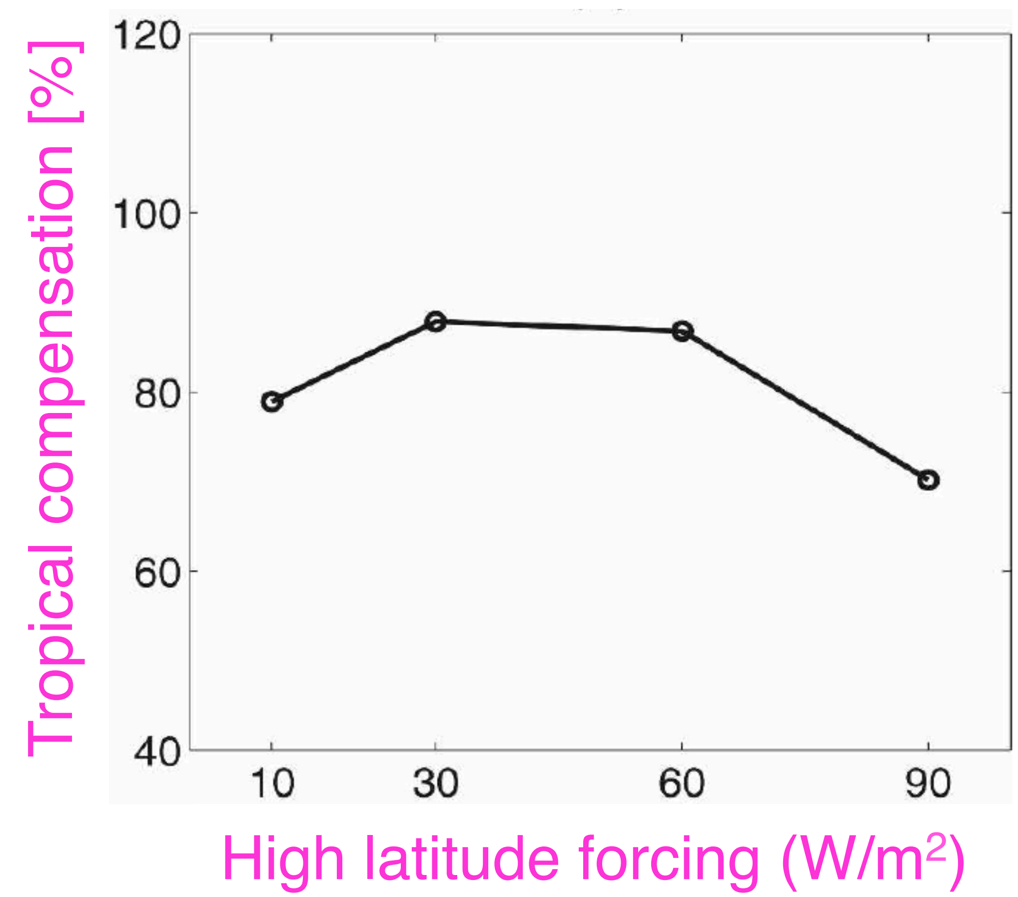
AGAUR for providing the research funding through Beatriu de Pinos program

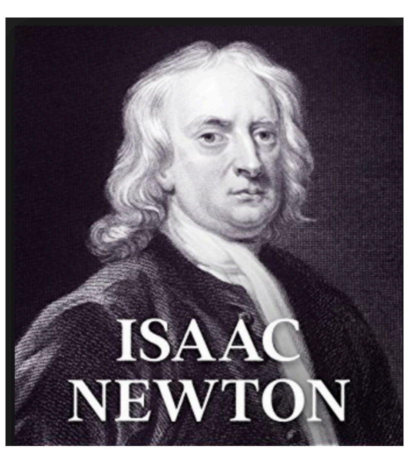
and

Xavier Levine, Rachel White, Pablo M. Ortega, Francisco Doblas-Reyes, Donald D. Lucas, Benjamin D. Santer, John C. H. Chiang for scientific support

Kang et al 2008, Journal of Climate:







3. Do not ignore fundamental physical laws